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Quick Reference

Chuck Brown, Maggie Stauffer, Chip Edstrom, and Marty Murphy have generated, or collected from previous versions, the material in this edition of the Switchyard Rookie Book. Corrections and additions are always welcome. We especially hope to keep the Tuning Guide current. Hopefully it can be kept in sync with any changes in the settings of the SY120 beam line or the MTest and MCenter beam lines as they are modified to follow the requirements of various experimental users. Please help us by bringing any incorrect or obsolete material to our attention.

Note about this version:

During the Tevatron Fixed Target run, 800 GeV beam was split in Switchyard on one of three possible paths: west down the Meson line, straight on to Neutrino & Muon lines, or east down the Proton line. The Meson, Neutrino/Muon and Proton areas themselves were further split into several more beamlines, serving a multitude of users.

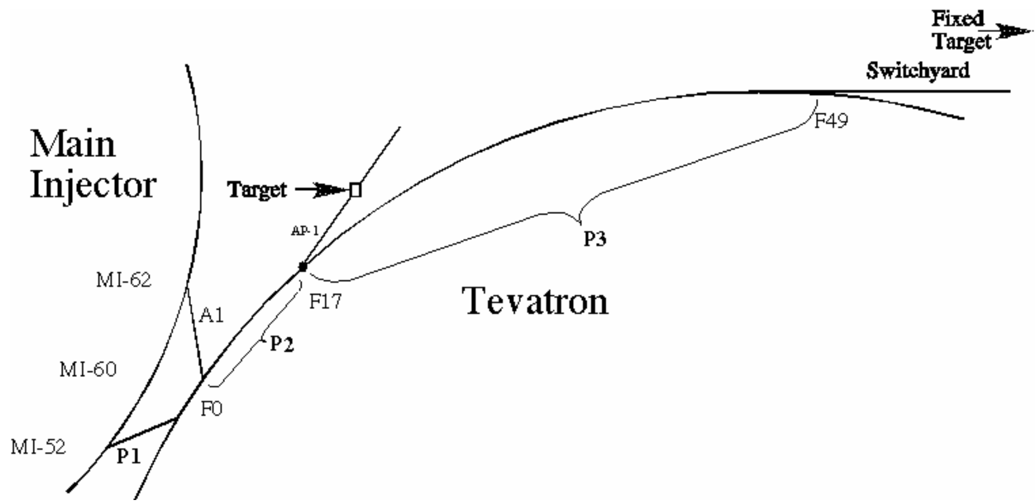
Currently, the Tevatron is used for HEP collider physics and no longer delivers 800 GeV beam to Switchyard. Instead, 120 GeV beam is delivered by the Main Injector, extracted into the P1, P2 & P3 lines, and then continues on to the Switchyard, where it traverses Enclosures B and C and the F-manholes, finally arriving in the Meson Area, the only remaining operational Fixed Target area. In M01, beam is further split into two beamlines that serve our two existing users at this time, Meson Center and Meson Test.

In the current operations, a very small fraction of the Switchyard and the Fixed Target Areas are used, compared to the days of yore. However, in the course of your travels you may encounter obsolete devices, power supplies, tunnel enclosures and service buildings. To that end, some notes in this Rookie Book provide historical information that you might find handy to know. Rest assured that we have made every effort to include only *relevant* obsolete information!

Happy trails.

Chapter 1: General Information

GEOGRAPHY



Main Injector

Beam destined for Switchyard is accelerated to 120Gev in the Main Injector on a $21 event. It can be extracted in two ways: slow spill and single-turn extraction. Slow spill, currently the most common operational method, uses the QXR quadrupole circuit to resonantly extract beam over several seconds. In single-turn extraction, beam is extracted with the MI-52 kicker/Lambertson combination.

P1 line

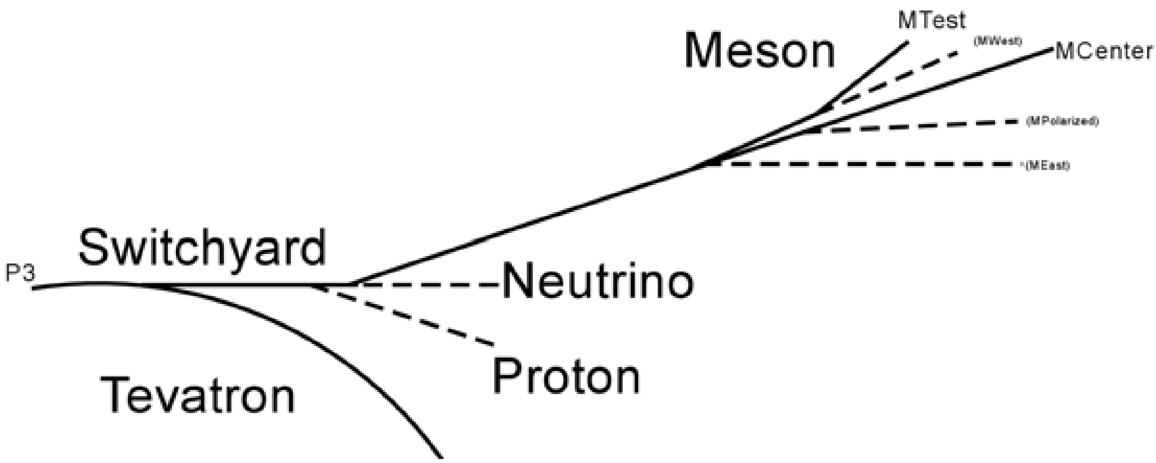
The P1 line starts in the Main Injector at the 52 location and bends beam up toward the Tevatron, ending at T:ILAM at Tevatron location F0. Besides spill to Meson, this line is used for proton injection into the Tevatron and beam to and from Pbar.

P2 line

For extraction to Switchyard and Pbar, beam coasts straight through T:ILAM into the P2 line, which extends from F11 to F17. If I:F17B3 ramps to high current, beam will be deflected into the AP1 line; otherwise, beam continues through to the P3 line.

P3 line

The P3 line, sometimes referred to as the ‘Main Ring Remnant’, follows the curvature of the Tevatron from F17 to F49. All magnets in the P3 line are powered by S:HP3US, S:HP3DS & S:QP3; HP3US & DS, which power the dipoles, are the critical devices for Switchyard enclosures B & C.



Switchyard

Switchyard officially begins at F49, where the P3 line ends and the beamline branches away from the Tevatron to continue onwards to the “Continental Switchyard,” i.e. Enclosures B and C, D & E.

Early in Enclosure C is the beam’s first opportunity to branch in one of two directions. The value of vertical trim S:VT103, located in downstream Enclosure B, determines whether the beam will pass through the field-free region of S:MLAM to the SY dump (located in Encl C), or through the field region to be bent west and continue through the beamline to Meson. S:MLAM1 & 2 (along with S:V204) are the critical devices for the F-manholes and Meson.

Next up is the F1 manhole, notable for containing the FSEP electrostatic septa which split the beam vertically into 3 streams.

Finally, the three streams of beam continue through the F2 and F3 manholes to the first Meson Area enclosure, M01.

Note about Enclosure C, D & E

This Switchyard enclosure is a combination of three beamline tunnels. The western tunnel, C, contains the beamline servicing Meson. The Neutrino beamline formerly traveled straight ahead through the G1 stub and the G2 manhole. The Proton beamline traveled through enclosures D & E on to J. Enclosure J was once part of this same enclosure; however, the interlocked gate has been moved from the downstream end of enclosure-J to the downstream end of enclosure-E. Though Encl J is now a separate enclosure, the key fobs still reflect the historical name “C, D, E & J.”

Meson

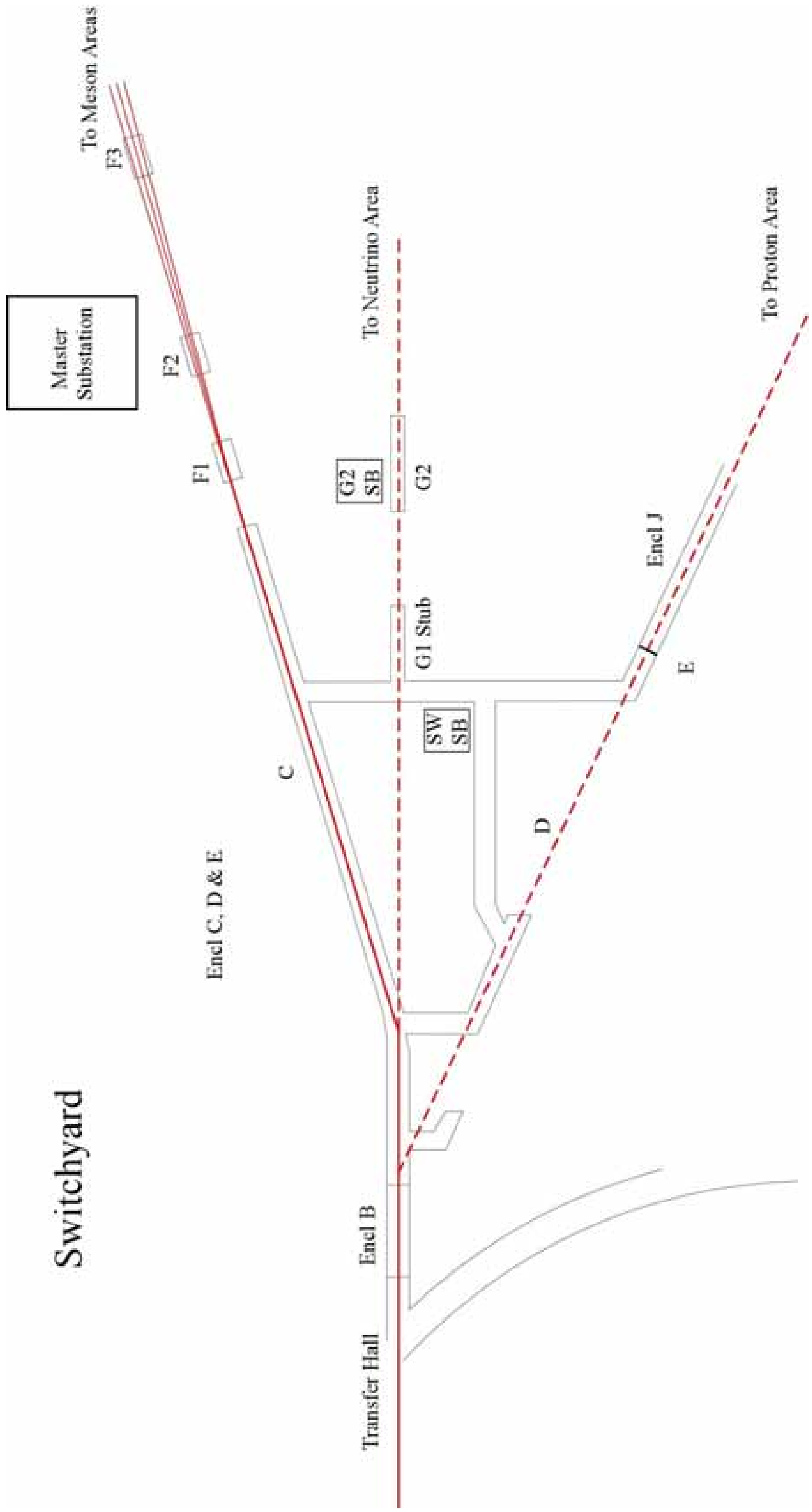
At the upstream end of M01, the 3 vertical streams of beam (which have now diverged to about 1 inch apart) are first bent horizontally by M01D. The center stream of protons travels through the center, field-free region of the MW1W/ME1E 3-way Lambertson magnet. F:MC1D, the critical device for MC6, MC7 & MC8, then bends the beam downward into the MCenter beamline. The upper stream is bent horizontally into the MTest/MWest beamline by F:MW1W, the the critical device for MTest enclosures MT6-1 and -2. If the critical devices are off, the Meson Target Train collimators absorb the beam. Sadly for the lower stream, this is always its fate; the MEast beamline and its critical device, F:ME1E, are decommissioned and permanently locked off.

MTest and MCenter share enclosures M01, M02, M03 and M05. By the end of M05, the beamlines have diverged sufficiently so there is finally room for independent enclosures, target halls, and shielding for each beam line. MTest concludes in enclosures MT6-1 & -2, while beam to MCenter continues through enclosures MC6 to MC7. MC8 and the empty MBottom enclosure MB7 do not contain any MCenter beam line elements, but due to radiation concerns, they must be interlocked during MCenter beam operation.

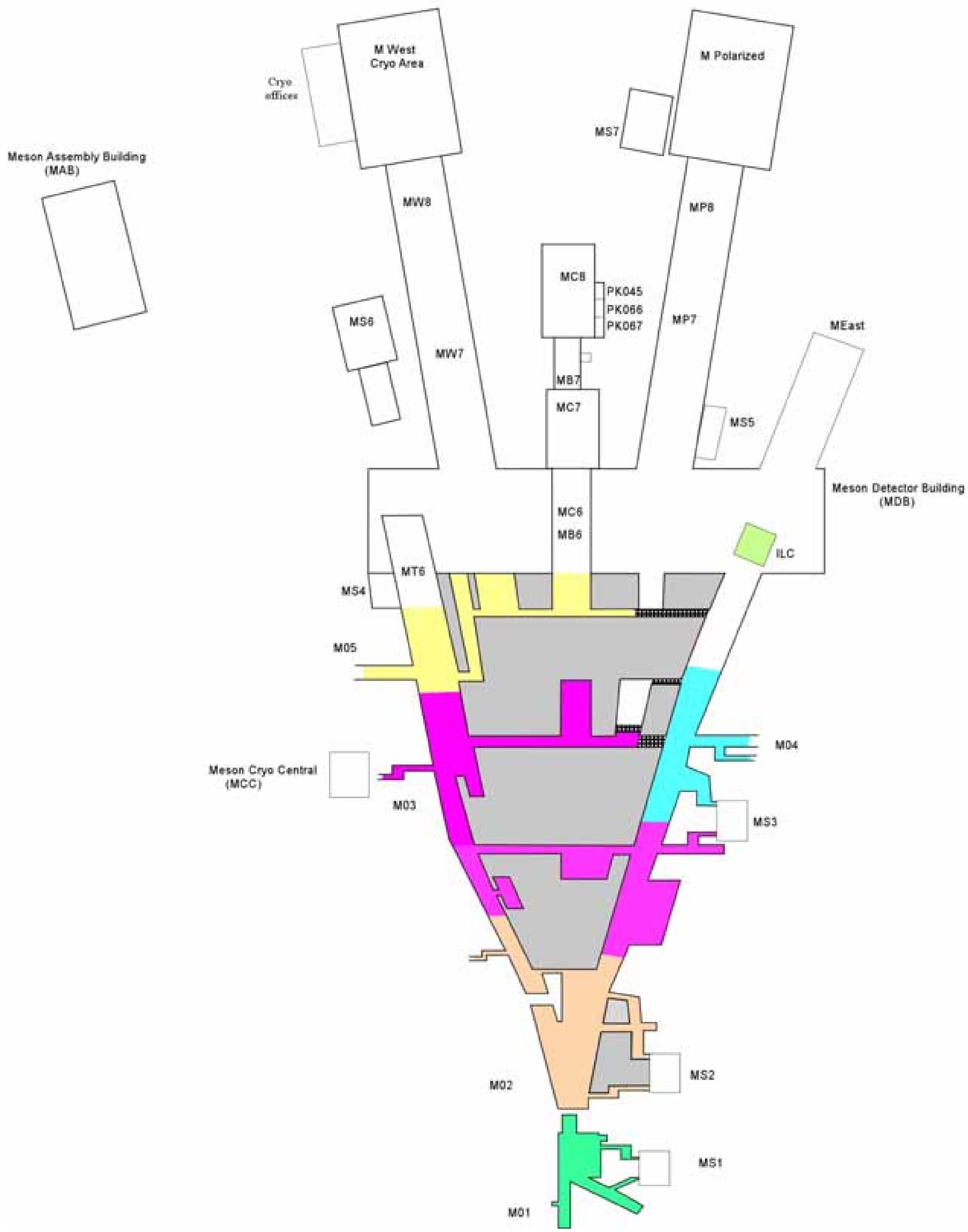
Historical note: Border dispute

Technically, the Meson area begins at M01; however, there are Meson devices, F:M00U, F:M00H and F:M00V, located in the Switchyard F2 and F3 manholes. These devices are powered by supplies located in MS1; other Switchyard F-manhole devices are powered by supplies in the G2 service building. So, rather than thinking of Meson beginning at M01, one can consider Meson to “begin” with the devices powered at MS1, even though they are located in the F-manholes.

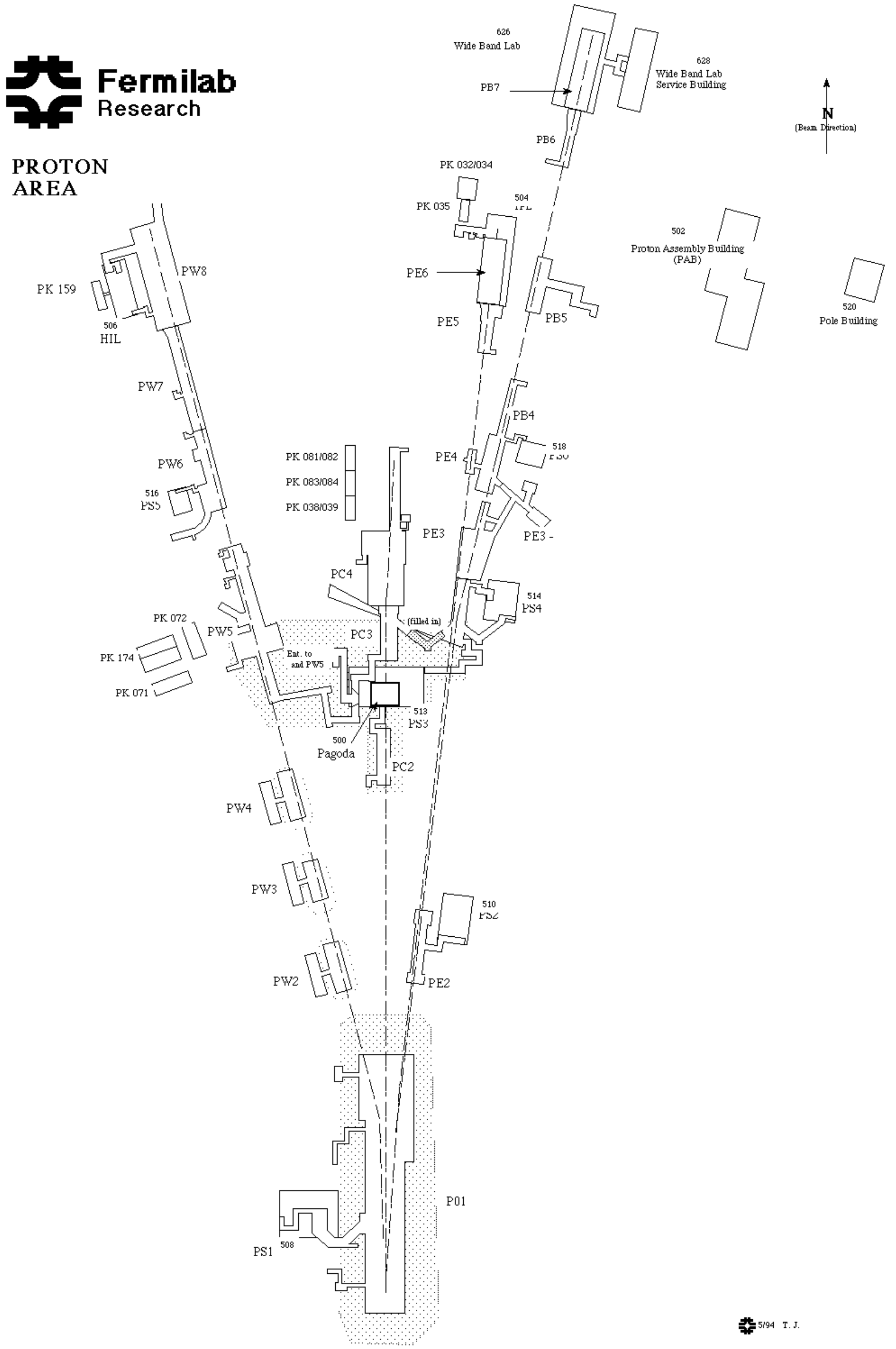
Switchyard Enclosure Map



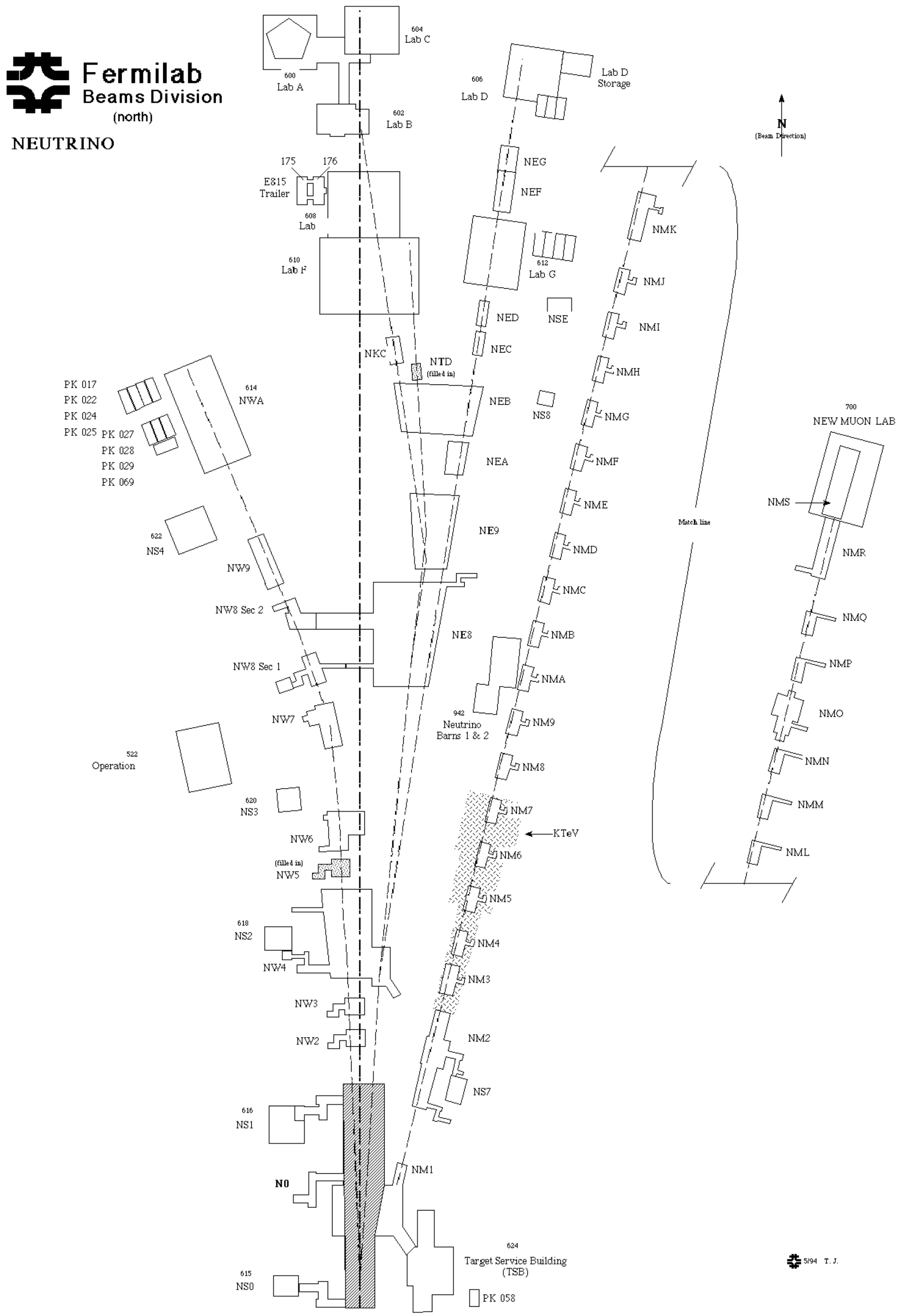
Meson Enclosure Map



Proton Area Map



Neutrino Area Map



NAMING CONVENTION

Switchyard

Switchyard devices are prefixed by S: and are of the form:

S:DN or **S:ND** (vacuum devices only)

D. Device Type

Q	-	Quadrupole magnet
V	-	Vertical dipole magnet
H	-	Horizontal dipole magnet
VT	-	Vertical trim magnet
HT	-	Horizontal trim magnet
L	-	Loss monitor
S	-	SWIC
HP	-	Horizontal BPM
VP	-	Vertical BPM
BV	-	Beam valve
IV	-	Isolation valve
RV	-	Roughing valve
RP	-	Roughing pump
BL	-	Blower
TC	-	Thermocouple
CC	-	Cold cathode

N. Number of the tunnel location/associated beamline based on the numbering scheme:

Magnet Number	Lines Affected	Location
Less than 100	Meson, Neutrino, Muon, Proton	Transfer Hall
100-109	Meson, Neutrino, Muon	Enc. B
100-109	SY Dump, Neutrino, Muon	Enc. C
110-119	Neutrino, Muon	Enc. G1
120-129	Neutrino	Enc. G2
420-429	Muon	Enc. G2
200-209	Meson	Enc. C
210-219	Meson	Enc. F1
220-229	Meson	F2 Manhole
230-239	Meson	F3 Manhole
300-306	Proton	Enc. B, C, D
307-319	Proton	Enc. E

Loss monitors contain a descriptive name, such as the name of the magnet they're nearest. For example, LH90 is the loss monitor found on top of the H90 magnet.

A magnet and its associated power supply generally have the same name. In the case where more than one magnet is powered by the same supply an appropriate name is chosen.

The D/A (setting) of a magnet's power supply will always be positive; however, the A/D (readback) can be either polarity, which sometimes(!) indicates useful information about the direction of the magnet's influence on the beam. The convention is (but don't trust polarities ever!):

A/D Polarity	+	-
Quad	Focus	Defocus
Vertical Dipole	Up	Down
Horiz. Dipole	West	East

Fixed Target

Enclosure names are of the form

ABC

A. Area

M - Meson
N - Neutrino
P - Proton

B. Beamline

0 - Special case where the device or enclosure contains multiple beamlines
T - Test
W - West
C - Center
B - Bottom
E - East
P - Polarized
M - Muon
K - KTeV

C. Enclosure number – 1-9, continuing with A-Z if there are more than 9

Example: the enclosure name MC6 means:

M = Meson area
C = Center
6 = The 6th enclosure containing Meson Center beamline

The Meson Area beamline devices are prefixed with an F: (for Fixed Target) and are of the form:

F:ABCDDD

D. <u>Device Function</u>

Q	-	Quadrupole magnet
W	-	West-bending dipole magnet
E	-	East-bending dipole magnet
U	-	Upward-bending dipole magnet
D	-	Downward-bending dipole magnet
V	-	Vertical trim magnet
H	-	Horizontal trim magnet
T	-	Toroid magnet
S	-	Spoiler magnet
AN	-	Analyzing magnet
CH	-	Horizontal collimator
CV	-	Vertical collimator
CF	-	Fixed-hole collimator
TCOL	-	Pinhole collimator
TGT	-	Target
WC	-	Wire chamber (SWIC)
PWC	-	Proportional wire chamber
IC	-	Ion chamber
SEM	-	Secondary emission counter
BS	-	Beam stop
BD	-	Beam dump
SC	-	Scintillation counter
CC	-	Cerenkov counter
L	-	Loss monitor
TLM	-	Total loss monitor
RP	-	Roughing pump
TP	-	Turbo pump
MV	-	Manual valve
BV	-	Beam valve
RV	-	Roughing valve
AV	-	
BL	-	Blower
PG	-	Pirani gauge

Example: The device name F:M01D-2 means:

F:	=	Fixed target device
M	=	Meson area
0	=	Contains multiple beamlines
1	=	Enclosure number 1
D	=	Downward-bending dipole
-2	=	The second magnet in a string of magnets called M01D

Note about M03/M04

In the past, M03 & M04 were divided in the same straightforward manner as other enclosures (M04 was downstream of M03 and both contained MT & MC devices). In 2005, the gates were rearranged, and now M03 contains the entire length of MTest & MCenter beamlines between M02 & M05; M04 has no operational devices in it. **Hence an exception to the naming convention:** devices named MT3, MC3, MT4 and MC4 are now all in the M03 enclosure. However, since M03 & M04 share a key and an ESS this doesn't affect what gets turned off for an access; they are separate enclosures only for the search and secure.

Service building names are typically of the form

ASC,

where "S" stands for Service.

There are various assembly buildings, equipment and control rooms, laboratories, and other buildings in the Fixed Target area that have names with very little or no association to their beamline location. They were named a long time ago and now we're stuck with them.

Here is a list of external beamline building names, what the names mean (if there are explanations), and where the buildings are located:

HIL	High Intensity Lab; associated with PW8
Lab A	Associated with NWB
Lab B	Associated with NCG
Lab C	Associated with NCH
Lab D	Associated with NEH
Lab E	Associated with NCF
Lab F	Associated with NCE
Lab G	Associated with NEE
Large White Barn	White barn located near enclosures NW8 and NMC
MAB	Meson Assembly Building
MCC	Meson Central Cryogenics
MDB	Meson Detector Building
MSB	Magnet Storage Building; located near PAB
New Muon	Associated with NMS
Old Muon	Associated with NWA
PAB	Proton Assembly Building, located east of PE5
Pagoda	Associated with PS3
Pole Building	Small building located just east of PAB
Small White Barn	White barn located near enclosuresNW8 and NMC
TPL	Tag Photon Lab; associated with PE6
TSB	Target Service Building (Linked to N01 via tunnel)
WBL	Wide Band Lab; associated with PB7

Chapter 3: Power Supplies

Every device in the tunnel is hooked up to one or more power supplies. Switchyard and Meson devices, however, are different from the accelerators' in that most devices have their own individual power supplies and ramp generators, rather than a common bus.

The exception to this rule is the P3 line (also known as the Main Ring Remnant), which is powered primarily by 3 main power supplies: S:HP3US, S:HP3DS, and S:QP3. QP3 powers all the quads in the P3 line. HP3US powers the upstream Main Ring-style dipoles between F17 and F34, and HP3DS powers the remaining (downstream) dipoles from F35 to F48. These two dipole power supplies are the Switchyard critical devices.

All 3 of these power supplies are powered by MOS 89, so they do not require extra LOTO for F-sector access. However, some of the downstream quads and dipoles extend into Transfer Hall (which begins at F47), which is why HP3DS and QP3 (but not HP3US) must be switched off and LOTOed for Transfer Hall access.

At present there are seven different types of power supplies used in Switchyard & Meson:

* TRANSREX-500kW
* TRANSREX-240kW
* LING
* ACME
* P=EI 20kW
* Glassman
* 4-Quadrant Corrector Supplies

TRANSREX 500kW

These are high-voltage, high-current power supplies. They are used on the large, conventional-type magnet strings. They have a maximum output of 500kW, hence the name. The Transrex-500kW is the only type of supply to be put in series with another supply (for S:MLAM, F:M01D, and each of the MCenter analyzing magnets F:MC7AN1 & F:MC7AN2). In these cases, only one supply is connected to ground. The Transrex-500kW supplies have a maximum output of 5000 Amps at 100V, or a maximum voltage of 400 VDC at 1250 Amps depending on the settings of the internal voltage and current taps.

TRANSREX-240kW

The Transrex-240kW power supply maximum outputs are 1200 Amps at 200 VDC or 800 VDC at 300 Amps. This type of supply is currently only used for 3 devices: F:M00U, F:MW1W and F:MC1D.

LING

The Ling power supply was specifically designed for Switchyard quadrupoles. Of these, only Q100, Q101 and Q202 remain on Lings (the rest are powered by 4-Quadrant Corrector supply trims). The Ling is a 55 kW power supply with maximum 200 Amps and 550 VDC, not simultaneously.

ACME

Acme supplies are used exclusively in Meson; they power a few dipole magnets and all quads except the high-current F:MC6Q2 & 5. They are rated at 50kW (500V/100A) or 22.5kW (225V/100A).

P=EI 20kW

These small 20kW P=EI (Power Energy Industries) power supplies have a maximum current of 200 Amps and maximum voltage of 100 VDC (not simultaneously).

GLASSMAN

There is only one Glassman supply in Switchyard, which powers the FSEPS septa magnets.

4-Quadrant Corrector Supplies

Three corrector supplies are used in Switchyard for trim dipoles and quads: CPSTG, CPSSY & CPSG2. Each bulk supplies power to a number of regulators; each regulator powers one dipole or quad trim, which can be run ramped or DC. It is necessary to reset the bulk in order to clear trip status on any individual corrector. There are many versions of this supply used around the complex; Switchyard supplies are rated at 50A/120V.

Trim Chassis Inventory

	Transfer Hall	**Enclosure B**	**Enclosure C**	**F Manholes**
	Q80	HT100	VT201	
	HT90	VT101	Q201	
S:CPSTG	VT91	VT102	Q203	
	VT92	VT103	Q204	
	Q90	Q102	Q205	
			HT105	
			VT105	
			HT201	
			HT202	
S:CPSSY			VT202	
			Q206	
			Q207	
			Q208	
				HT210
S:CPSG2				VT210
				QT210
				QT211

Switchyard Power Supplies & Loads

Device	PS Type	Location	Encl	Load
S:HP3US		F3	F-sector	MR dipoles (57)
S:HP3DS		F4	TH, F-sect	MR dipoles (46)
S:QP3		F4	TH, F-sect	MR quads (28)
S:HT90	S:CPSTG	TG9	TH	TRIM
S:VT91	S:CPSTG	TG9	TH	TRIM
S:VT92	S:CPSTG	TG9	TH	TRIM
S:Q90	S:CPSTG	TG9	TH	QUAD
S:VH94	Transrex 500-5	TG8	TH	2 EPB
S:HT100	S:CPSTG	TG9	B	TRIM
S:Q100	Ling	TG8	B	QUAD
S:VT101	S:CPSTG	TG9	B	TRIM
S:Q101	Ling	TG8	B	QUAD
S:VT102	S:CPSTG	TG9	B	TRIM
S:Q102	S:CPSTG	TG9	B	QUAD
S:VT103	S:CPSTG	TG9	B	TRIM
S:MLAM	Transrex 500-5 (2)	TG8	C	2 LAM
S:Q201	S:CPSTG	TG9	C	QUAD
S:Q202	Ling	TG8	C	QUAD
S:HT105	S:CPSSY	SSB	C	TRIM
S:VT105	S:CPSSY	SSB	C	TRIM
S:VT201	S:CPSSY	SSB	C	TRIM
S:HT201	S:CPSSY	SSB	C	TRIM
S:H201	Transrex 500-5	SSB	C	14 EPB
S:Q203	S:CPSTG	TG9	C	QUAD
S:HT202	S:CPSSY	SSB	C	TRIM
S:Q204	S:CPSSY	SSB	C	QUAD
S:VT202	S:CPSSY	SSB	C	TRIM
S:Q205	S:CPSTG	TG9	C	QUAD
S:Q206	S:CPSSY	SSB	C	QUAD
S:H202	Transrex 500-5	SSB	C	14 EPB
S:H203	Transrex 500-5	SSB	C	EPB
S:Q207	S:CPSSY	SSB	C	QUAD
S:Q208	S:CPSSY	SSB	C	QUAD
S:V204	Transrex 500-5	SSB	C	2 EPB
S:VT210	S:CPSG2	G2	F1	TRIM
S:QT210	S:CPSG2	G2	F1	QUAD
S:HT210	S:CPSG2	G2	F1	TRIM
S:QT211	S:CPSG2	G2	F1	QUAD
S:FSEP	Glassman	G2	F1	SEPTA (2)
F:M00H	P=EI	MS1	F2	4-4-30
F:M00V	P=EI	MS1	F2	2.5-5.125-40
F:M00U	Transrex 240-1.2	MS1	F3	3 cooling ring dipoles

Meson Power Supplies & Loads

Device	PS Type	Location	Encl	Load
F:MW1W	Transrex 240-1.2	MS1	M01	6 3-way Lambertsons
F:MC1D	Transrex 240-1.2	MS1	M01	(1) Modified B1
F:M01D	Transrex 500-5 (2)	MS1	M01	(7) Modified B1's
F:MT2Q1	ACME	MS2	M02	3Q120
F:MT2Q2	ACME	MS2	M02	3Q120
F:MT2WD1	Transrex 500-5	MS2	M02	(2) 5-1.5-120 (EPB)
F:MT2WD2	Transrex 500-5	MS2	M02	(3) 6-3-120
F:MT2V	P=EI	MS2	M02	4-4-30
F:MT2WU	Transrex 500-5	MS2	M02	(5) 5-1.5-120 (EPB)
F:MC2Q1	ACME	MS2	M02	3Q120
F:MC2Q2	ACME	MS2	M02	3Q120
F:MC2V	P=EI	MS2	M02	5.5-2.87-60
F:MC2H	P=EI	MS2	M02	5.5-2.87-60
F:MT3Q1	ACME	MS3	M03/M04	3Q120
F:MT3Q2	ACME	MS3	M03/M04	3Q120
F:MT3V	P=EI	MS3	M03/M04	4-4-30
F:MT3W	Transrex 500-5	MS3	M03/M04	(2) 5-1.5-120 (EPB)
F:MT3SW	Transrex 500-5	MS3	M03/M04	5-1.5-120 (EPB)
F:MT3U	ACME	MS3	M03/M04	(2) 3D120
F:MT4Q1	ACME	MS3	M03/M04	3Q120
F:MT4Q2	ACME	MS3	M03/M04	3Q120
F:MT5V	P=EI	MS4	M05	4-4-30
F:MT5Q1	ACME	MS4	M05	3Q120
F:MT5Q2	ACME	MS4	M05	3Q120
F:MT5E	Transrex 500-5	MS4	M05	(5) 5-1.5-120 (EPB)
F:MC5Q1	ACME	MS4	M05	3Q120
F:MC5Q2	ACME	MS4	M05	3Q120
F:MC5H1	ACME	MS4	M05	4-4-30
F:MC5V1	ACME	MS4	M05	4-4-30
F:MC5U	Transrex 500-5	MS4	M05, MC6	(3) 5-1.5-120 (EPB)
F:MC6H1	P=EI	MS4	MC6	4-4-30
F:MC6H2	P=EI	MS4	MC6	4-4-30
F:MC6V1	P=EI	MS4	MC6	4-4-30
F:MC6V2	P=EI	MS4	MC6	4-4-30
F:MC6Q1	ACME	MS4	MC6	(2) 3Q120
F:MC6Q2	Transrex 500-5	MS4	MC6	4Q120
F:MC6Q3	ACME	MS4	MC6	3Q120
F:MC6Q4	ACME	MS4	MC6	3Q120
F:MC6Q5	Transrex 500-5	MS4	MC6	4Q120
F:MC6Q6	ACME	MS4	MC6	3Q120
F:MC6D	Transrex 500-5	MS4	MC6	(4) 5-1.5-120 (EPB)
F:MC7AN1	Transrex 500-5 (2)	MS5	MC7	Jolly Green
F:MC7AN2	Transrex 500-5 (2)	MS5	MC7	Rosie

Chapter 4: Magnets

Like any directed beam, the Switchyard and External Beamlines require magnets to direct the beam and confine the beam to the beam pipe until it is delivered to its destination. This chapter assumes a basic understanding of magnets and related components. For a review of concepts and basic magnet configurations see the chapter on Magnets in the Accelerator Concepts Rookie Book. As such this chapter will concern itself more with the kinds of magnets one can expect to find in the Switchyard. These include Lambertsons, Septa, EPB Dipoles, 3Q120 Quads, Main Ring B2 Dipoles, Main Ring Quads and Trims.

Lambertsons

Lambertsons are special magnets with two or three apertures as shown in *fig 1*. One aperture is designed to be a field-free region, allowing beam to pass along its initial trajectory through the Lambertson. The other aperture or apertures have bend fields across them and will direct beam such that it leaves the Lambertson at an angle. If the dipole-field region of the Lambertson is not powered, however, no bend occurs and beam is not deflected by the Lambertson. For this reason Lambertsons are used as critical devices. Switchyard is no exception, using S:MLAM1 and S:MLAM2 as critical devices for the Meson Primary beam permit and F:MW1W (the upper half of the MW1W/ME1E three-way Lambertson) as the critical device for MWest/MTest.

fig 1: (a) A two-aperture Lambertson such as S:MLAM1/2. (b) A three-aperture Lambertson such as F:MW1W/ME1E

Septa

A septum splits beam along a plane defined by a row of grounded wires along the length of the septum. Parallel cathodes on either side of the wires are charged to a high potential resulting in a strong electric field across each gap. The beam on either side of the wires is deflected by the field. Septa are most useful where you wish fine splitting control over the amount of beam to two or more locations.

The FSEPS in Switchyard control how much beam is sent to MTest and MCenter with the remainder going to the Meson Target Train dump. The FSEPS are oriented to affect a vertical deflection. As seen in *fig 2*, FSEP7 is responsible for sending beam to MTest and FSEP8 divides the remainder between MCenter and the Switchyard Dump. While one can adjust upstream and downstream positions for the septa, in practice they should remain relatively level and both upstream and downstream stepper motors should be adjusted in a mult or with S:FSEP7T or S:FSEP8T. For more information on tuning with the septa see the Tuning Guide.

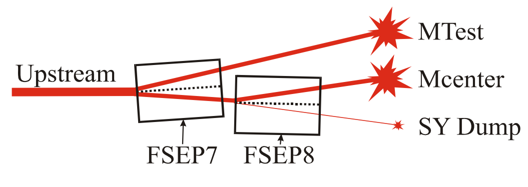


fig 2: A side-view of the FSEP layout.

EPBs

EPB, or External Proton Beam, dipoles are conventional dipoles used throughout switchyard. They have a 1.5” high gap by 4” gap width and are 120” long (a few 60” long EPBs exist also). The can be excited to a maximum field strength of about 15 kG at 1700 A. Due to their light weight and hence poor field uniformity at high excitation, they are usually designed to run below about 1500 A. They provide the bulk of the bending power in the Switchyard and Meson Lab Beamlines.

3Q120 Quads

3Q120 quads have a 3” Internal Diameter (ID) and are 120” long. They have a maximum field gradient of about 5 kG/in at 100 A. These quads are poorly cooled and are quite old so for the sake of safety and longevity, they are usually run below 80 A.

Main Ring B2 Dipoles and Quads

The Main Ring B2 dipoles were one of the two standard types of dipoles formerly used in the Main Ring. The aperture is slightly less eccentric than the B1 dipole with a vertical aperture of 2” and a horizontal aperture of 4”. These, along with the Main Ring-style quadrupoles compose the bulk of the P1, P2, and P3 lines, known as the Main Ring remnant.

Trims

Trims are small, air-cooled dipoles used to correct the beam trajectory, particularly before splits and near experimental targets in the MTest and MCenter experimental areas. Many trims in the Switchyard run off of 4-quadrant corrector supplies.

Chapter 5: Diagnostics

The diagnostics available for checking on the beam trajectory through the SY120 beam line vary in the different sections of the Switchyard (basically for historical reasons only). Thus each section is addressed independently below.

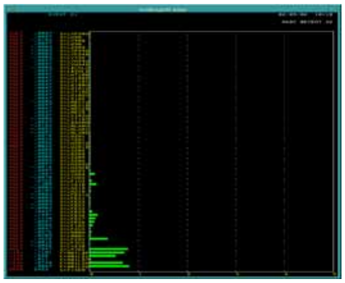
P1 and P2 Beam Line Diagnostics

The P1 and P2 beam lines are instrumented with **multiwire chambers, beam position monitors, beam loss monitors and toroids**. In addition to transporting beam to SY120, the P1 and P2 beam lines are also involved in the transport the high-intensity 120 GeV proton beam to the AP1 line for pbar production and the transport of 8 GeV and 120 GeV beams during pbar manipulations and Tevatron shots.

To preserve the emittance of the high-intensity beam to the AP1 line, the **multiwire chambers** are typically parked out of the beam. They can be used, one-at-a-time, for short periods, if permission is granted by the crew chief, pbar experts or run coordinator. The setup parameters to check on the beam positions in P1 and P2 for the SY120 $21 event with the multiwire chambers are (insert correct one here, use wrong one for spacer):

The SY120 beam is almost always run in slow spill mode. In this mode, the **beam position monitors and toroids** do not work. Experts are needed to run fast kicked beam on a $21 event if the BPMs and toroids need to be interrogated.

The **beam loss monitors** are sensitive to both the slow and fast spill SY120 beam. The ACNET pages displaying the beam losses on a $21 event in the P1 and P2 beam lines are:



P3 Beam Line Diagnostics

The P3 beam line is instrumented with **multiwire chambers, a SWIC and beam loss monitors**. There are no active beam position monitors in the P3 beam line.

S49 is a **SWIC** and the other 6 Chambers in the P3 line are **multiwire chambers**. They are typically left out of the beawea weaxm to help preserve the SY120 beam emittance. Note: inserting these chambers into the beam should be done with care between $21 events; if the SY120 beam hit one of these chambers as it was being inserted it could cause the Tevatron to quench. The beam position in P3 can be seen by configuring the chambers as shown:

(include here links to pictures of the appropriate ACNET displays)

The P3 **beam loss monitors** are connected to the old Main Ring loss monitor electronics (Marv Olsen is the expert). They can be interrogated by ACNET as shown: (include here links to pictures of the appropriate ACNET displays)

Continental Switchyard Beam Line Diagnostics

The SY120 beam line through the continental switchyard, Transfer Hall -> Enclosure B -> Enclosure C -> F1,2,3 manholes, is instrumented with **SWICs, beam loss**

monitors, and Secondary Emission Monitors (SEMs). Beam position monitors do exist in these enclosures but they are not connected to any readout hardware.

The **SWICs** in continental switchyard are often left in the beam (this helps create small multiple-scattering tails on the beam that allow for stable splitting of the SY120 beam, especially if the intensities requested by MTest and MCenter differ by a large factor.)

Gianni Tassotto and his crew monitor the SWICs, keep the gas flowing, etc.. Typical ACNET settings and displays of the SWICs are:

(include here links to pictures of the appropriate ACNET displays)

Gianni Tassotto and crew also monitor and repair the **beam loss monitors** in the continental switchyard. The losses can be plotted using the mew BLM display program, S43 as shown:

(include here links to pictures of the appropriate ACNET displays)

Secondary Emission Monitors (SEMs) measure the integrated beam intensity per pulse. The SEM in the F1 enclosure, S:F1SEM is useful for checking the transmission of the first 2 kilometers of the SY120 beam line as shown:

(include here links to pictures of the appropriate ACNET display)

If the apparent transmission as measured by S:F1SEM/I:BEAM21 is less than 75%, there is some anomalous beam loss somewhere upstream (see the tuning chapter).

Meson Area Beam Diagnostics

The SY120 beam is typically split vertically into three beams by the septa in the F1 enclosure. The upper beam is called the MWest/MTest beam line in M01 and beyond. The middle beam is called the MCenter beam in M01 and beyond. The lower beam (historically the MEast beam) is absorbed on the Meson Target Train in M01. The beam lines are monitored by **SWICs, SEMs, Ion Chambers, and scintillation counters** (in low intensity secondary beam regions). MTest and MCenter both have high intensity primary beam and low intensity secondary beam regions of the beam line. This large range of intensities that need to be monitored determines the diagnostics used to monitor the beam.

The **SEMs**, F:MW1SEM and F:MC1SEM, monitor the primary 120 GeV proton intensity in the two meson beam lines at the entrance to the Meson Target Train. Note that if the MWest beam line is not energized, the upper proton beam impinges off-center on F:MC1SEM and thus is reading is unreliable in this instance. Similarly, the lower or MEast beam always impinges on the lower edge of F:MC1SEM and again invalidates its reading if there is much intensity in the lower split beam.

When the MCenter beam is run in pion mode, the ion chamber, F:MC6IC, is used to monitor the primary proton intensity hitting the secondary beam production target in MC6.

In the secondary beam regions of MTest and MCenter, the beam intensity is low enough that individual particles, protons, pions, kaons and electrons, can be counted directly with scintillation counters. These counters need to be adjusted by experts to ensure that they are counting individual charged particles efficiently. If the rate of particles registered by a scintillation counter exceeds 1 MHz, the counter is probably becoming inefficient. Eric Ramberg is in charge of the scintillation counters, MT3SC to MT6SC4, in the M03 to MT6 enclosures of the MTest beam line and the MIPP experimental group is in charge of the beam scintillation counters in the MC7 enclosure of the MCenter beam line. Technicians in the Research Division have provided the scintillation counters in the past.

Chapter 6: Controls

This chapter will deal with controls of the Switchyard and External Beamlines. This includes looking at the TLG modules used for 120 GeV operation, the CAMAC link and associated cards used, and the QXR VME.

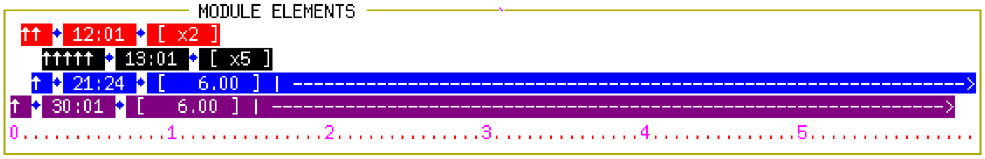


fig 1- TLG module 80, the standard 120GeV Fixed-target slow-spill module.

Nominally, beam is sent to SY120 in a slow spill employing QXR to deliver a roughly steady flow of beam through out the cycle. To do this a timeline with a slow-spill module, such as module 80, must be loaded into the timeline. Module 80, shown in *fig 1*, is roughly 6.2 seconds long with a 4.2 second flat-top, the later of which determines the length of the spill.

The first thing that should be noted about this module is that it is a multibatch module. One can see that from the number of Booster batches are being called for on the Booster reset for Fixed Target, $13. The module starts out by playing out a $30 indicating that SY120 will be taking beam. This is followed by two pre-pulses in Booster, on the $12s, and a Fixed Target reset in Main Injector, on the $21. Once this has happened, all the machines are ready and beam is injected into Main Injector, ramped to 120 GeV, and spilled to switchyard over about 4 seconds.

Fast Spill- what module? Changes: quad bumps turned off, Longbatch kicker set up for MI 1 turn extraction to SY.

CAMAC Link

Like other areas of the Fermilab complex, there is a CAMAC link stretching into Switchyard and like other areas of the Fermilab complex not all of what is on the Switchyard link actually pertains to switchyard. Several CAMAC

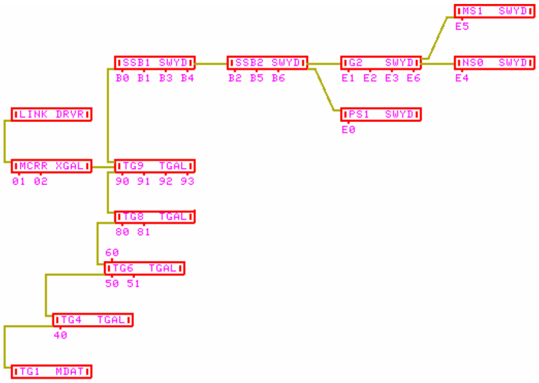


fig 2- The Switchyard CAMAC link.

crates in Transfer Gallery, in the MCR, and in the MAC room are also on the Switchyard CAMAC link. For information on this and the other CAMAC links around the complex see the Links section of the controls rookie book.

CAMAC Cards

The following is a list of the CAMAC cards used in Switchyard and the External Beamlines. Further information on each of these modules can be found at http://www-bd.fnal.gov/controls/camac_modules/c*XXX*.htm where *XXX* denotes the 3-digit module number. Many of these are touched on in the Controls Rookie Book in the Controlsopedia.

057 - A stepping-motor controller module.

080 - A parallel I/O interface module that acts as the interface module between a microprocessor and its associated CAMAC crate (such as in our BPM system). Some microprocessors use one parallel bus (Multibus) whereas the CAMAC Dataway is a different parallel bus.

117 / 217 - A Power Supply Controller. It requires a C119 as an interface.

118 / 218 - A Power Supply Controller. It requires a C119 as an interface.

119 - An interface between low level electronic controls and electro-mechanical power supply control devices.

165 - A power supply controller for many devices. The ramps are loaded from the MCR. The ramp is of the form:

$V_{out} = SF \times (V_t \times E)$

The scale factor, *SF*, is set by the D/A value entered by an Operator on a parameter page. The table value, V_t, is a time-dependent multiplier set from a C165 control page. The beam energy, *E*, is represented by MDAT and defaults to full scale if not specified.

170 - A CIA crate vacuum controller.

177 - A time delay module for many devices around the accelerator. Each module has 8 channels which may be triggered independently, and each may be referenced to as many as 15 TCLK events. Each channel has a programmable delay ranging for 1 microsecond to 65.535 seconds. Upon receipt of a trigger each channel that is enabled outputs a TTL pulse which may be used to trigger any other device.

178 - A TCLK repeater/decoder module. This module decodes the TCLK events and fans them out to the rest of the crate.

181 - Provides basic digital input and output control facilities. It is a modified version of the C180 module.

184 - Provides basic digital input and output control facilities. It is considered by the controls department equivalent to the C181 module and is recommended for new applications or as a replacement for a C181 module.

185 - Provides basic digital monitor facilities for devices.

190 / 290 - A module that interfaces the MADCs around the accelerator to the controls system. It can support up to 128 channels, and is capable of supporting up to 6 plots at a 2.1 kHz rate or a single channel at 70 kHz. It is able to determine which of the devices under its care are in an alarm state, and can decode events on the accelerator clock system.

200 - The Abort Concentrator Module. This card accepts up to 8 inputs from devices in a given service building. If the permit signal originating from a device disappears, an abort is generated, dropping the beam permit.

333 - A customizable module able to track up to eight 24-bit binary channels. Each channel can count inputs having a frequency in excess of 25MHz. Channels are cleared with TCLK events.

453 - A waveform generator/power supply controller. The ramps are loaded from the MCR. The ramp is of the form:

$V_{out} = SF_1 \times (m_1 \times f(t)) + SF_2 \times (m_2 \times g(M_2)) + SF_3 \times (m_3 \times h(M_3))$

Where SF_x are the scale factors, m_x is either 1 or a raw MDAT reading divided by 256, f(t) is a time based ramp, and M_x is an MDAT channel. The g and h ramps then correspond to their respective MDAT channel. The *f*, *g*, and *h* tables as well as SF_x, m_x, M_x, and trigger events can be set from a C4XX ramp control page.

489 - A common GPIB interface module with more memory than a C488

QXR VME

VME location

Controlling the VME (parameter pages)

Resetting memory/Rebooting

Memory Gain

Initial Level Setting

Chapter 7: Utilities

Vacuum

Vacuum requirements in the Switchyard and Fixed Target beamlines are considerably less stringent than in other parts of the accelerator, because protons only pass through once. The ideal pressure is around 1 to 10 microns (one micron = 10 E -3 torr), except for the septa, which need to achieve about 10 E -7 Torr to prevent sparking.

To isolate the Switchyard into different regions to accommodate the different requirements, "windows" made of ~3 mil thick titanium are installed at strategic points. The thickness is sufficient to withstand 1 atm pressure differential, but is practically transparent to 120 GeV beam. Windows are placed at either end of each set of septa. The windows are recognizable in the tunnel by the 5-1/2" quick-disconnect flange.

The beam line vacuum is maintained by a roughing pump/Roots blower combination. The Roots blower improves the vacuum by a factor of about ten. These pumping stations are continuously running. Both pumps operate simultaneously to maintain a vacuum of 10 E -3 torr. The relatively poor vacuum can be attributed to the limitations of pump capabilities and outgassing from the 14” carbon steel “sewer pipes” between enclosures.

Vacuum is maintained separately in the septa with ion pumps. Of course, a roughing pump and turbo are required for the initial pump-down, after which a valve isolates them. Pressure in the septa should be maintained around 10 E -7 torr.

Some of the decommissioned Neutrino, Muon and Proton beam lines in the Switchyard are also maintained under vacuum by the mechanical support group for preservation purposes. Be aware that some active devices are in the G1 stub of Encl C, D & E and G2 and show up on the G2 vacuum subpage.

Vacuum Components

Pirani gauges

Pirani gauges measure the vacuum in the beam pipe from atmosphere (760 torr) down to 1x10e-3 (1 micron). They are used throughout Switchyard and Meson.

The M01 Lambertson MW1W is interlocked to a Pirani gauge. If the gauge is not in an acceptable range the Lambertson magnet will not turn on.

M01 Lambertson M01PG1 <= 1.25 volts or .1 torr.

Cold Cathode Gauges

Cold cathode gauges measure vacuum levels below 10e-3 Torr (1 micron). Currently, the only cold cathode gauge in use in Swtichyard is FSCCI, which measures the vacuum at the only location required to achieve vacuum higher than 1 micron, the FSEP7 and FSEP8 electrostatic septa.

Mechanical pumps

Mechanical pumps operate down to about 10 microns (10e-2 Torr) and are used in the majority of the beamlines. Mechanical pumps have an oil-sealed chamber in which a series of round discs spin on a shaft. As the discs press against the walls of the chamber, air molecules are pushed toward an opening and vented into the atmosphere. A smoky vapor emanating from a mechanical pump usually implies that it is pumping large amounts of air, in which case the mechanical group should be notified.

Ion Pumps

Ion pumps are used on the FSEP septum magnets. They produce a vacuum by ionizing the molecules of air in the chamber, and driving them into a special material, which removes them from the chamber. Their range of operation is 10e-7 to 10e-8 Torr.

CIA Crates

The CIA crate is the electronic readout and controls hardware designed for the vacuum system. It has dedicated cards and slots for the different device types. One crate can handle up to 24 Pirani gauges, 24 cold cathode gauges, 12 valves and 4 pump setups.

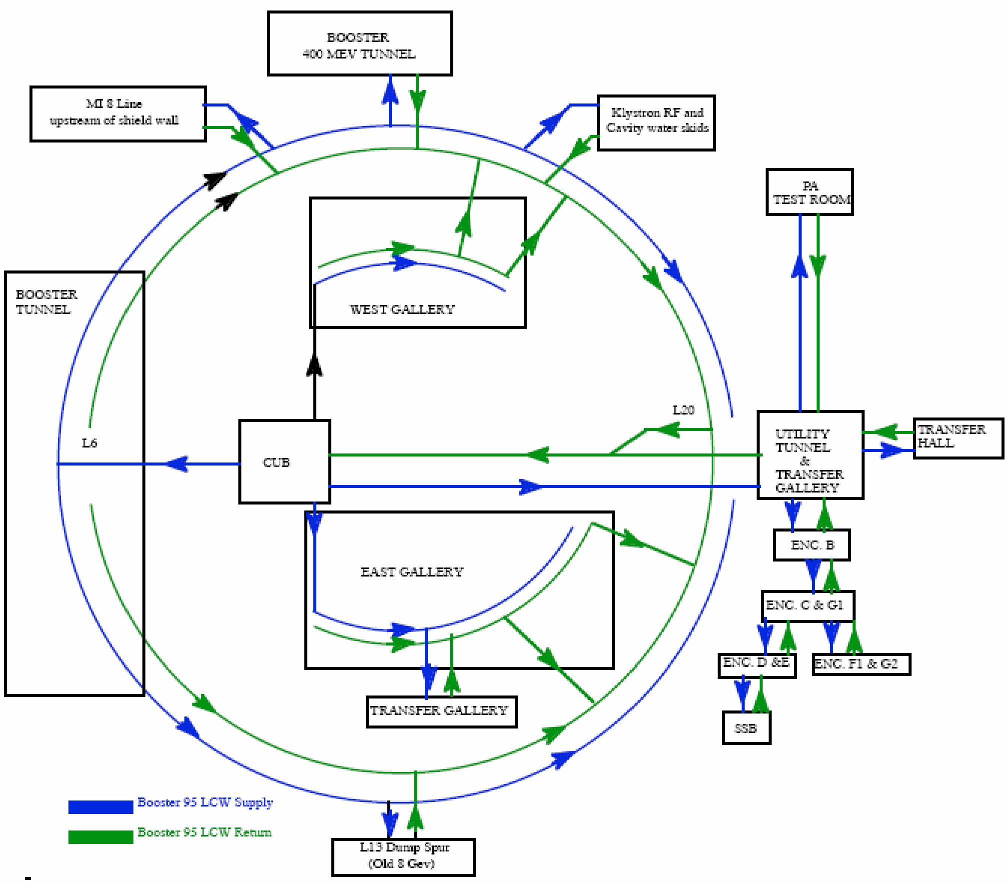
LCW

Switchyard

The LCW system for Switchyard is a branch of the Booster 95 degree system. From their origin at CUB, the supply and return lines enter the Utility Tunnel. Several taps in the tunnel provide cooling for Switchyard power supplies in the Transfer Gallery upstairs before the lines take a plunge into Enclosure B. For the most part, the lines run parallel to the magnets near the floor, often for long stretches of Switchyard that require no water cooling. (Trims, for example, are air-cooled.) When a string of EPB magnets appears, a small, separate set of headers is set up to supply it.

The main lines run all the way down Enclosures B and C, which also supplies EPB magnets in F1 and G2, as well as G2 service building power supplies. There is a major branch near the beginning of V100 that supplies enclosures D and E; eventually SSB power supplies tap off this line. The supply pressure is kept at about 120 psi, and the return at about 40 psi.

The P2 and P3 line magnets and power supplies are cooled by the Tev 95 LCW.



MESON LCW

Meson magnet and power supply cooling is provided by 2 LCW systems (MS2 & MS6) and one RAW system (M01). Start-up instructions are located at the skid.

MS2 LCW

MS-2 LCW system services enclosures F2, F3, M01, M02, M03, M04, M05 and upstream devices in MC6 (up to MC6Q3), as well as power supplies in service buildings MS1, MS2, MS3 & MS4.

System Operation

This system normally requires **one pump** for proper operation. The normal system operating pressure is approximately 180 psi.

> **PLEASE NOTE:** During the winter some of the MS-2 air towers are blanked off and tagged. **Do Not** fill these towers or turn on the fans. All of the fans in this system have the 'Hand' position switch disconnected.

MS4 LCW

The MS4 LCW system is not currently used.

MS6 LCW

MS-6 LCW system services MC6 downstream devices (after MC6Q4), MC7, MC8, MB7, MT6-1, MT6-2, MP7-9, MP Lab, MW7-9, MW Lab, ME7-8, and ME worm, as well as power supplies in service buildings MS5, MS6 & MS7.

System Operation

This system normally requires **two pumps** for proper operation. The normal system operating pressure is approximately 230 psi.

MESON RAW

A smaller cooling system is the **RAW** (**R**adio**A**ctive **W**ater) system. It's a closed loop system, totally isolated from all other cooling systems. This is necessary because its primary function is to cool target piles and beam dumps, which cause the water to become highly radioactive or tritiated. **The RSO must be notified before any work done on a RAW system, or in case of a leak.**

M01 RAW System Operation

This is the only RAW system currently in use in Switchyard or Meson. It is used to cool beam absorber pile between M01 and M02 (usually called the Meson Target Train). The system has the rated heat load capacity of 150 kW. It also features computer readouts and variable flow rates of 5 to 60 gpm with a constant pressure of approximately 115 psi.

System Features

Incorporated in this system are the following:

1. The M01 RAW system requires only LCW cooling to satisfy the Radiation Safety Group. On RAW systems with a maximum load of 150 kW or RAW installations in which the cooling water must be supplied at a temperature lower than can be provided by the LCW, we have installed a water-to-water heat exchanger that uses ICW to pre-cool the LCW to a lower temperature. This eliminates the need for costly and complicated chillers that have been used in the past. **On the M01 RAW system the water-to-water heat exchanger portion of the system is not used.**
2. The surge tank in this RAW system is open to atmosphere. This helps release any hydrogen build-up that may occur and eliminates the need for recombiners and extra alarms.
3. The main control box for this system is located in the MS-1 service building. The front face of the control box is diagramed to give the operator a visual readout of the RAW system it is operating. A flow diagram of the RAW system contains indicators for flow rates and temperatures. Lights are provided on the front of the control box to give the operator an 'instant' look at the RAW system status.

Composition of a Water System

LCW (Low Conductivity Water):

LCW starts as industrial water from one of Fermilab's ponds that is processed through a deionizer loop, which takes minerals out of the water.

ICW (Industrial Cooling Water):

ICW is industrial water from one of Fermi’s ponds. We use Casey’s pond.

Pre-Strainer

A pre-strainer removes rocks, dirt, and other debris from the industrial water before it goes to the LCW system.

String Filters

This is a more refined means of filtering the industrial water. It filters-out debris not caught in the pre-strainer.

Deionizing Loop

The deionizing loop consists of 4–6 deionizer bottles, which contain a mixture of anion and cantion. The bottles act as filters, removing minerals found in the industrial water, thereby lowering the electrical conductivity of the LCW system. This filtering process is known as “polishing” and prevents electrolysis across the ceramic voltage potentials of the magnet and deterioration of the hose barbs in power supplies and the system piping. A RAW system has only one deionizer bottle.

Resistivity Meter

The Resistivity Meter measures the electrical conductivity of the LCW water. It helps to determine if the LCW system needs more “polishing” as well as indicating when the deionization bottles need replacing.

3-way Makeup Valve

This valve allows the circulation of LCW water through the deionizing loop or 'make-up' water (ICW) to fill the system.

Expansion Tank

The expansion tank allows for expansion and contraction of the water due to the temperature changes during operation and for monitoring the system's water level. Float switches in the tank indicate the water level. Alarms are shown by LEDs on the front control panel. The float switches are called:

1. Low Level
2. High Level
3. Make-Up On
4. Make-Up Off

LCW Pumps

There are usually 2–3 pumps per system driven by 40, 50, 100, or 150 horsepower AC induction motors. The RAW systems have two pumps but only one is used. The second pump is valved off and used as a backup.

Variable Speed Controller

Variable Speed Controllers were implemented in some water systems to adapt to changing magnet loads. Its flexibility allows the cooling system to match the heat load without changing different pump configurations. It is used alone during shutdown to keep the system "polished" and for special running of analysis magnets.

Water-to-Water Heat Exchanger

It is a shell and tube construction wherein LCW water passes through the shell side of the exchanger and cooling ICW water in the tube. This is a controlled process when ICW cooling is required. The RAW systems usually have two heat exchangers, ICW-to-LCW and LCW-to-RAW.

Water-to-Air Cooling Towers

This is a radiator-type construction wherein return LCW water from the magnet and power supplies pass through air towers. Electric-driven fans turn on to control the temperature.

Water-to-Water Heat Exchanger with Air Cooling Towers

Pre-cooling air towers help conserve ICW cooling water needed for the heat exchanger during the summer. The air towers are not used in the winter.

PLEASE NOTE: Air Cooling Towers are for emergency use only.

Air Compressor

This provides required air pressure to the system. The air pressure is regulated at 70 psi.

Pressure Regulated Valve

These valves regulate the pressure for other devices in the system that require lower pressure. The relief valve relieves pressure if the pressure is greater than the set point.

Pressure Gauges, Pressure Controller and Pressure Switch

These devices monitor pressures, maintain regulated pressures, and indicate if pressure is 'good' or 'bad' in all systems.

1. Power supply rooms require 120 psi for operation.
2. LCW operating pressure is between 180–260psi.
3. RAW operating pressure is 115 psi, 160 psi for a "Big Brother" RAW system.

Controls Box

The control box contains the electronic circuitry used to monitor the water temperatures, flow rates, and expansion tank water level of each system. Red LEDs located on the front panel of the control box indicate alarm conditions.

Under certain alarm conditions, the control box circuitry will shut down the system. LCW control boxes are blue and the RAW boxes are red. Their design and function are basically the same.

Flow Probes

The Flow Probes monitor the flow rate in the header pipes as well as the total flow of the system. Flow rates for a RAW system vary from 5 gpm to 60 gpm. The normal flow rate through a RAW deionizing loop is 5–10 gpm. The normal flow rate through a LCW deionizing loop is 15–20 gpm.

Temperatures Probes and Gauges

The Gauges monitor the Supply and Return temperatures for each water system. The Probes indicate real temperatures that are converted into an electrical signal, which is used in the systems control box.

Chapter 8: Meson Beamlines

The Meson Beamlines, MTest and MCenter, currently service two experimental areas, the Meson Test Facility in enclosure MT6 and the MIPP spectrometer in MC7. The two beam lines are designed to operate more or less independently; changes in the running conditions of one should not affect operations in the other and beam may be provided to one experiment or both experiments without special configuration changes. Both the Mtest beam and the MCenter beam have a 120 GeV proton mode of operation and a lower energy, secondary hadron beam mode of operation. These two modes are usually referred to as the proton mode and the pion mode to indicate the majority species of particle type incident on the experimental detectors in the secondary beam line.

Meson Center

Meson Center, commonly referred to as MCenter, can be divided into two distinct areas. The first is the primary proton beamline, which runs from MC1D to the MC6 enclosure. At the upstream end of MC6, the beam interacts with a long, narrow solid Target. The resultant particles enter the MC6 spectrometer, are momentum analyzed, and then transported to the experimental area MC7.

Meson Test

Meson Test, or more commonly MTest, can be divided into two distinct areas. The first is the primary proton beamline, which runs from MW1W to the pinhole collimator in the MT3 enclosure. There, if in proton mode, most of the beam is absorbed on the pinhole collimator. The attenuated beam is then transported to the Meson Test Facility in MT6.

In pion mode, the beam interacts with an 18” Aluminum target on the Meson Target Train creating copious pions at 0°. The MT2W1 double dipole string then separates the secondary hadrons from the more copious uninteracted 120 GeV proton beam. The pions are then transported to the MT6 test facility.